

Spectrum Analysis in Mineralogy

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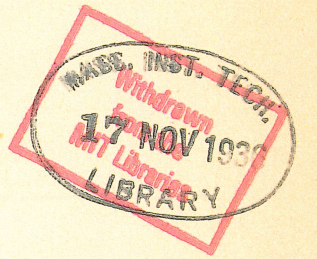
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I. Introductory.

Spectrum analysis is being widely adopted in mineralogical laboratories, as an accessory means of identification of mineral species, and for investigations into their chemical composition. There is, however, no convenient summary of the technique to be employed in mineralogical spectrum analysis or of the results which the methods have yielded. The writer has been engaged in work on the spectrum analysis of minerals and of metals for Messrs. Adam Hilger, Ltd., and has thus read the scattered literature of the subject, making it convenient to prepare the present review.

The first worker in the field of mineralogical spectrum analysis was Hartley, who published his first paper in 1884: in this paper he initiated investigations into quantitative spectrum analysis which later received much attention from workers in Dublin. De Gramont, in a lengthy series of papers beginning in 1895, not only worked on some theoretical aspects of spectrum analysis, but also evolved a reliable technique for determining the presence of a particular metal in a mineral. He published descriptions of the spectra of a great many minerals, which, though they may be no longer necessary for their spectrographic identification, indicate the wide range of application of the methods. Since about 1920, many workers have adopted these methods, as can be seen from the bibliography.

In addition to the analysis of minerals, this review deals with the analysis of rocks and of meteorites, which has been carried out by some workers, although difficulties are here experienced in obtaining small representative samples. X-ray spectrum analysis requires a highly specialised technique and is therefore only dealt with in outline. Identification of minerals by means of their absorption spectra is another recent development, treated in the last section.

II. The Technique of Spectrum Analysis.

- (a) Excitation of the spectrum.
- (b) Preliminary treatment of the mineral.
- (c) Optical apparatus.
- (d) Spectroscopic technique.
- (e) Spectrographic technique.

(a) *Excitation of the spectrum.*—For spectrum work with minerals, in the visual and ultra-violet parts of the spectrum, four methods of excita-

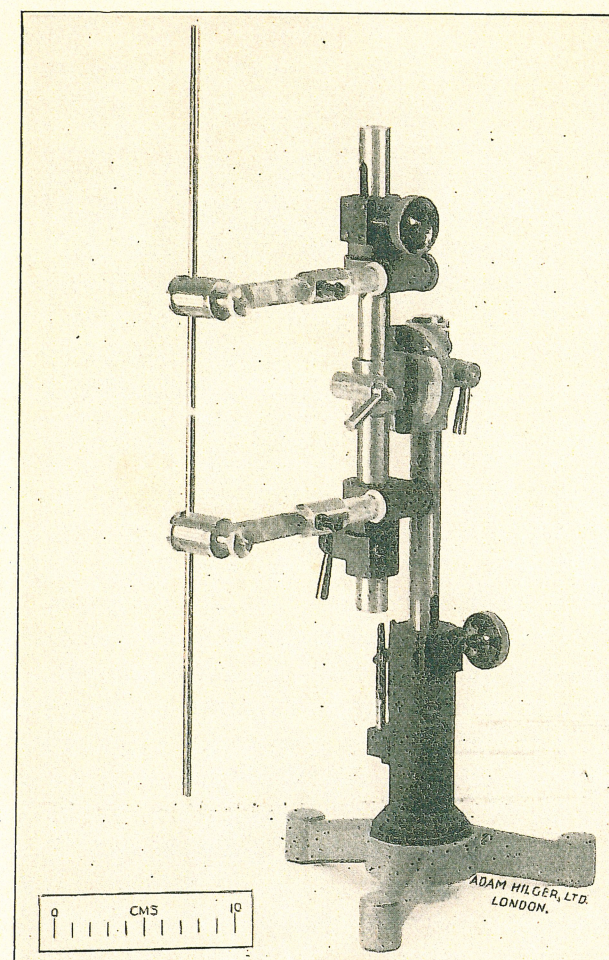


FIG. 1

tion need to be considered, namely, high-temperature flames, the electric arc, the condensed spark discharge and the vacuum tube discharge. The mineral under examination is treated in one of several ways available

to obtain a pair of electrodes—as is described fully in later sections,—and these electrodes are clamped in a holder of the type shown in Fig. 1.

The high-temperature flames which have been employed are :—

- (i) Oxy-coal gas.
- (ii) Oxy-hydrogen.
- (iii) Oxy-acetylene.

Hartley and Ramage used (ii), and de Gramont (iii), while (i) was used to a much smaller extent by Brun. A suitable refractory must be used to hold the mineral under examination : Hartley and Ramage used kyanite supports, while de Gramont used carbons. The oxygen and hydrogen are stored under compression, and the acetylene is most conveniently handled

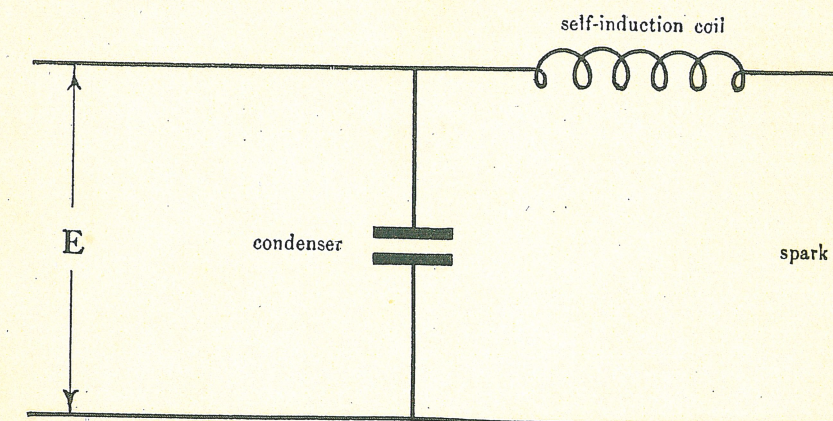


FIG. 2

in cylinders of dissolved acetylene under pressure. Coal gas is taken from the laboratory supply. The flame is directed upon the mineral by means of oxy-hydrogen or oxy-acetylene blow-pipes of the usual laboratory type.

The arc is obtained by connecting the terminals of the holder (Fig. 1) to a D.C. supply of 150 to 220 volts, with carbon filament lamps arranged in parallel to give a current of 3 to 6 amps. The arc is struck by allowing the electrodes to touch and then separating them by a few millimetres, or by touching both electrodes with a graphite rod, insulated at one end by having a strip of rubber tubing slipped over it. If A.C. only is available, only carbon arcs can be run, but they are suitable for many purposes. The material to be examined should always be placed on the positive pole of the D.C. arc.

The apparatus required for producing a spark discharge consists either of an induction coil, or, preferably, of a small transformer, which should be capable of giving about 15,000 volts on open circuit. A condenser is placed across the spark gap, and for certain classes of work a small self-induction coil is useful. Fig. 2 shows the arrangement of the circuit,

E representing the applied high potential from the transformer. If an A.C. supply is not available for the transformer, a small rotary converter must be added to the outfit. Fig. 3 shows the apparatus set up for producing a spark discharge, together with the condensing lens and the slit end of the spectrograph in position for taking a photograph.

A few workers have used compound methods of excitation. Thus de Gramont frequently used a condensed spark on a melt heated with a Meker burner, while Ramage has used an arc on which an oxy-hydrogen flame was directed.

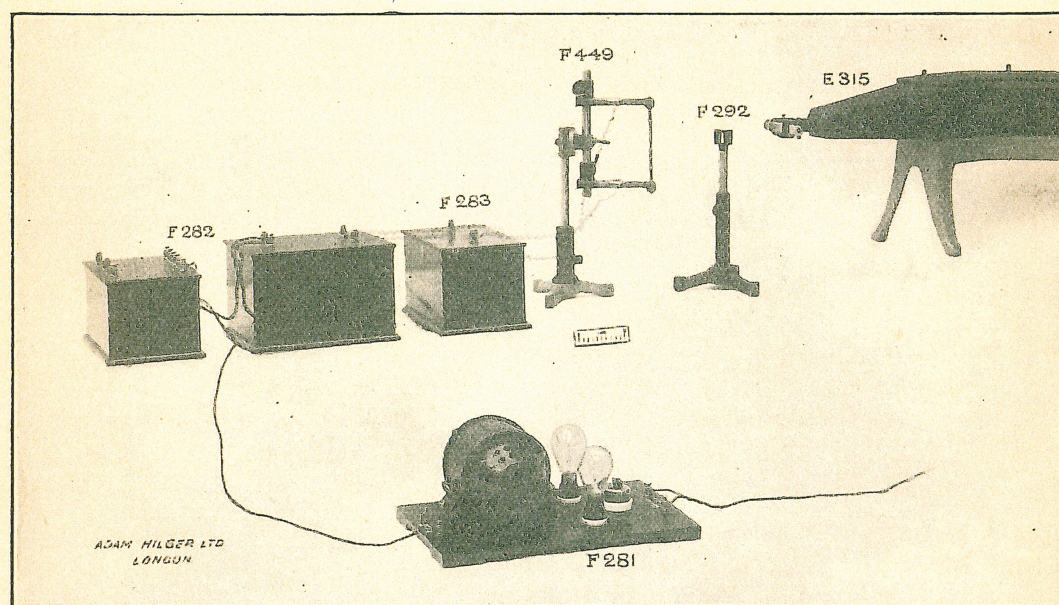


FIG. 3

The fourth method, the vacuum tube discharge, is not suited to the analysis of minerals, as the spectrum given rarely shows any lines due to the electrodes, but only those due to the rarified gas in the tube. Such a method was used, however, in the recognition of helium in the gas evolved when certain minerals related to uraninite were heated, but it seems to have had no other application in mineralogy.

The mode of excitation to be adopted depends on the nature of the mineral and the particular purpose of the analysis.

For the alkalis, alkaline earths and thallium, the high-temperature flames are most successful, and also suffice for a limited number of the heavy metals. The spectra of the rare-earth elements comprehend a very large number of lines varying not greatly in intensity, and exhibit few lines which are both characteristic and intense. These circumstances make their spectra difficult to interpret.

For general qualitative work, the identification of mineral grains, and the search for rare elements, the arc is the most generally useful.

Where approximate quantitative results are required, the condensed spark is especially valuable, as the intensity of the light given off is kept more constant than with the other sources. The condensed spark also reveals lines of a number of metalloids which do not appear so well with the other means of excitation, namely tellurium, phosphorus, arsenic, antimony, carbon, silicon and boron.

(b) *Preliminary treatment of the mineral.*—The spectrum of a mineral can be excited without any previous treatment under the following circumstances:—

When high-temperature flames are used.

When the arc is used.

When the condensed spark is used, if the mineral is a conductor.

Generally, then, there is no treatment necessary except with non-conducting (*i.e.*, most non-metallic) minerals which it is desired to examine with the spark, and several methods have been devised to meet this case.

De Gramont fused the non-conducting mineral in a small platinum cup with sodium or lithium carbonate, by heating with a Meker Burner, thus obtaining a conducting melt.

Others, notably Hartley and his co-workers, brought the minerals into solution, and submitted the liquid to the spark discharge in tubes of various kinds, the design of which has recently been modified by Dr. Hitchen and the author. Löwe has excited the spectra of solutions by introducing them into the crater of a carbon arc with a pipette, and striking an arc between this impregnated carbon and an upper one.

Other modifications of procedure with the arc have been devised for dealing with small grains of friable minerals. Thus Crookes compressed the powdered material with very pure silver powder, obtaining a solid electrode. Giusca embedded his minerals in molten lead or zinc. In most of such cases, however, the mineral can be successfully treated in the carbon arc.

The most satisfactory way of using spectrographic methods in mineral analysis is to run them in conjunction with complete chemical analyses, as has recently been done by a group of Italian workers, including Porlezza and Donati and Carrobbi, and by a number of Japanese mineralogists who have contributed a series of eight papers with the general title "The Chemical Investigation of Japanese Minerals Containing Rarer Elements." Each of these two schools has analysed spectrographically (in the arc) the original mineral and each precipitate arising in the course of the analysis. This is particularly necessary with the rare-earth metals which are difficult to separate.

(c) *Optical apparatus*.—Experience has shown that for analytical purposes prism instruments are preferable to grating instruments. In mineral analysis, both spectrosopes and spectrographs may be necessary. A useful visual instrument for use with minerals is shown in Fig. 4. It is of the "Direct Reading Wavelength Spectrometer" type.

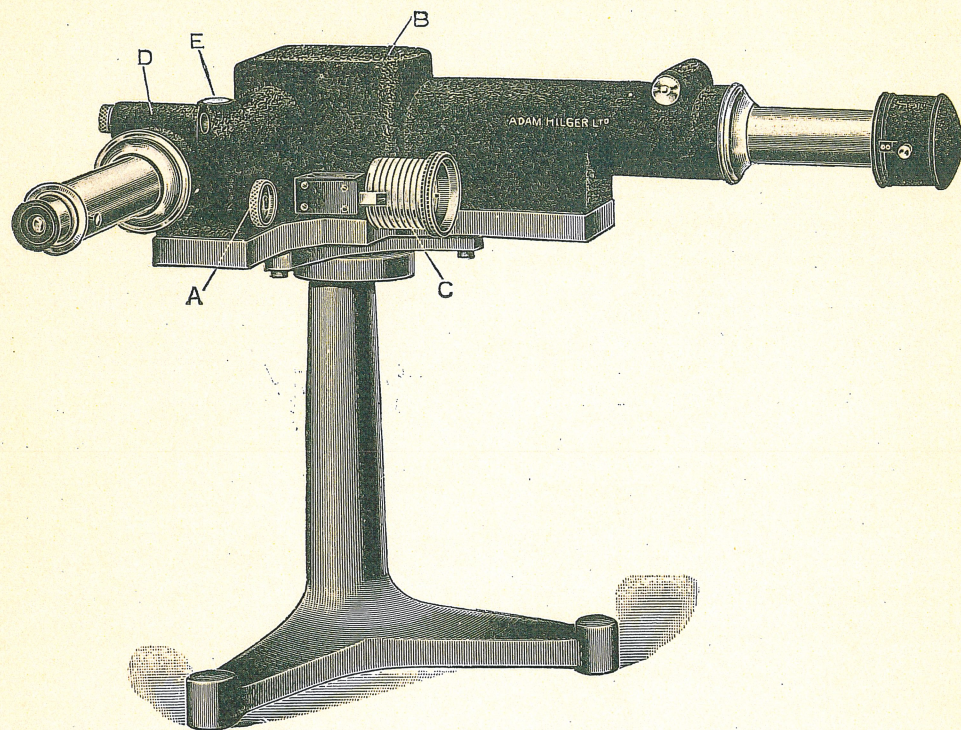


FIG. 4

The location of any line can be found readily by means of the graduated drum C.

Many of the sensitive lines of the elements, *e.g.*, those which are present in the spectrum when the percentage of the element is very low, occur in

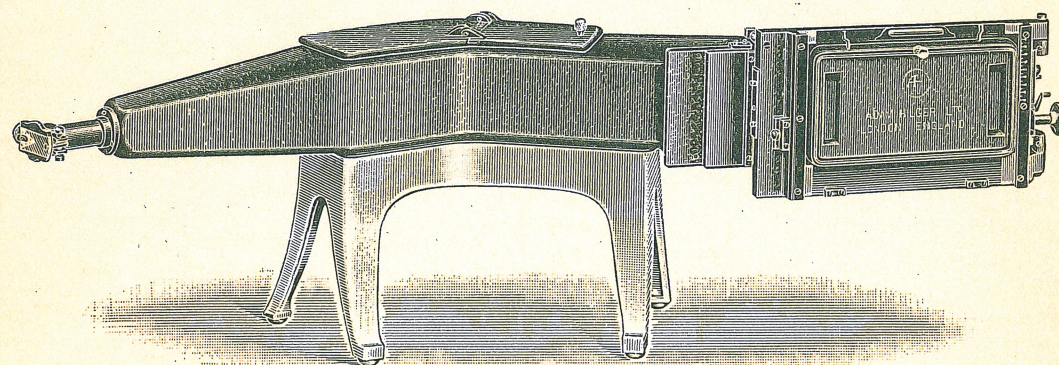


FIG. 5

the ultra-violet region of the spectrum, and consequently it is often necessary to photograph the spectrum. For a similar reason, it is usually essential to have the optical train of the spectrograph entirely of quartz, as this is more transparent to the ultra-violet rays than is glass. The dispersion necessary depends on the type of mineral which is being examined. For general work, a spectrum from 2000 Å to 10,000 Å on a single 10 × 4 inch plate is all that is required,—such an instrument being the medium quartz spectrograph shown in Fig. 5. For minerals having very complex spectra, however, an instrument with a wider dispersion is required—such as the larger one shown in Fig. 6, which covers approximately the same range of wavelengths on four plates of the same size. The larger instrument is necessary for minerals whose dominant constituent is one of the following metals:—

Chromium	Titanium
Cobalt	Tungsten
Iron	Uranium
Molybdenum	Zirconium
Nickel	

It is also preferable, but not essential for the analysis of minerals whose major constituent is one of the following:—

Manganese	Vanadium
Thorium	

In each case it is necessary to have a condensing lens to focus the light from the arc or spark on to the slit of the instrument. A spherocylindrical lens is customary, since it gives a line-image of the source, and tends to "average" any variations in the nature of the emission from different parts of the light source.

Special pieces of apparatus required for special purposes are described in later sections.

(d) *Spectroscopic technique*.—When using the spectroscope, the light source is set up at the distance specified in the maker's instructions, and aligned by observation through the eyepiece with a wide slit. The condensing lens is then introduced and aligned so that the image of the source of light falls on the plane of the slit, which is then narrowed to about 0.02 mm., a convenient width for working.

Wavelengths of the lines are determined approximately by bringing them on to the eye-piece pointer, and reading off the wavelength in Å. from the graduated drum C, Fig. 4.

(e) *Spectrographic technique*.—With a spectrograph, the manipulation for alignment is as described above, the dark slide being removed during the process, and the visual region of the final spectrum examined with a small eyepiece. When this has been done, a photographic plate is put in

the dark slide, which is placed in position on the spectrograph. The shutter of the dark slide is drawn up, and the exposure made by uncovering the slit for the time of exposure (usually 30 secs. to 3 mins.) and covering it again. For the control of the exposure a small metal shutter is sometimes provided.

The choice of plates presents little difficulty: panchromatic plates are required to photograph the visual end of the spectrum, and Schumann Plates are of occasional use for the ultra-violet below 2100 Å, while for some of the quantitative methods dealt with in a later section, process plates are required, but generally speaking any of the commercial plates are suitable, though they must usually be ordered "on thin glass."¹ Development is carried out as in ordinary photography.²

III. The Qualitative Analysis of Minerals.

Under this heading there are two broad types of problem which can be solved by spectrum analysis.

- (a) Testing a mineral for the presence or absence of a particular specified metal.
- (b) Examining a mineral to determine all the metals present.

The usual procedure in each of these two cases will be considered.

(a) *To ascertain whether a mineral contains a specified metal.*—If a visual instrument is employed, a pair of electrodes of the metal to be sought are set up in an arc lamp, or a fragment of that metal or one of its compounds is put on one of the electrodes of a carbon arc. The arc or spark is then applied and one of the "lasting lines"³ located approximately by means of the graduated drum C: this is then brought directly on to the eyepiece pointer.

The drum is left in this position, and the mineral under examination placed in the crater of the lower of a fresh pair of carbons. The eye is kept at the eyepiece while the arc is struck, and it is observed whether any line appears opposite the pointer. If it does, the metal in question is present; if not, it is absent. The conclusion is confirmed by similar observations with one or more of the other "lasting lines." The electrodes should, of course, be of the highest purity.

¹ The reason being that for securing critical definition in the modern quartz spectrograph the plate is slightly curved in its holder (see, for instance, the Publishers' list of spectrographs).

² Fuller details of the technique of spectrum analysis will be found in "The Practice of Spectrum Analysis" (1s. 7d. post free) and "Foundations and Methods of Chemical Analysis by the Emission Spectrum" (the authorised translation of Gerlach and Schweitzer's "Die Chemische Emissionspektralanalyse") both 12s. 9d. published by Adam Hilger, Ltd.

³ These are ascertained by reference to "Visual Lines for Spectrum Analysis," D. M. Smith. Published by Adam Hilger Ltd., London.

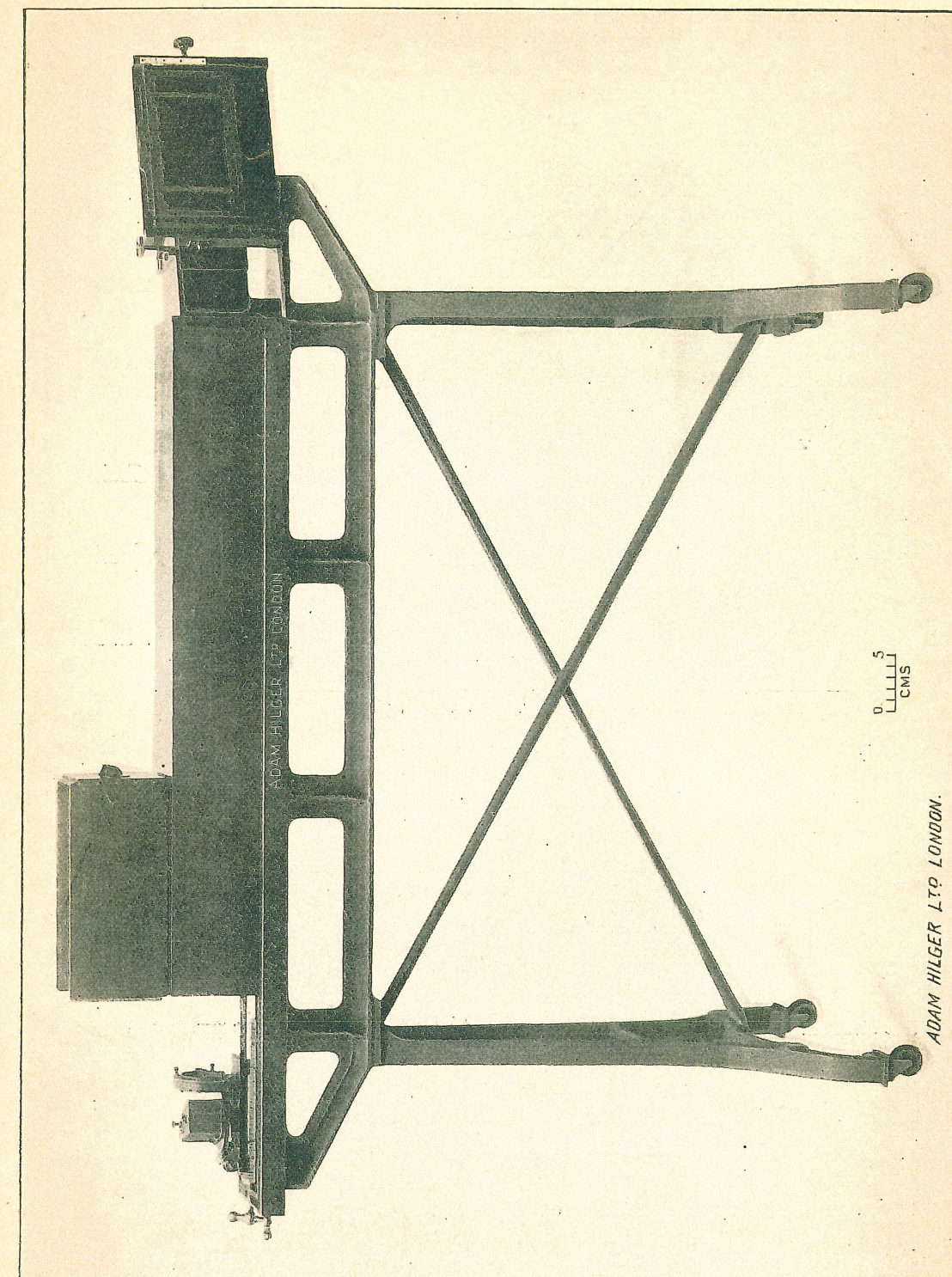


Fig. 6

The procedure with a photographic instrument is somewhat different. In front of the spectrograph slit is a sliding plate with three square apertures arranged *en echelon*. This is called a "Hartmann" diaphragm. With the bottom hole in position over the slit take a spectrogram of the carbon or other electrodes alone, or of any metal (in the purest form obtainable), which is known to be in the mineral in considerable quantity. Without moving the dark slide or shutter of the camera, and with the middle hole in position, take a spectrogram of the mineral under test. Again, with the top aperture in position, and without moving dark

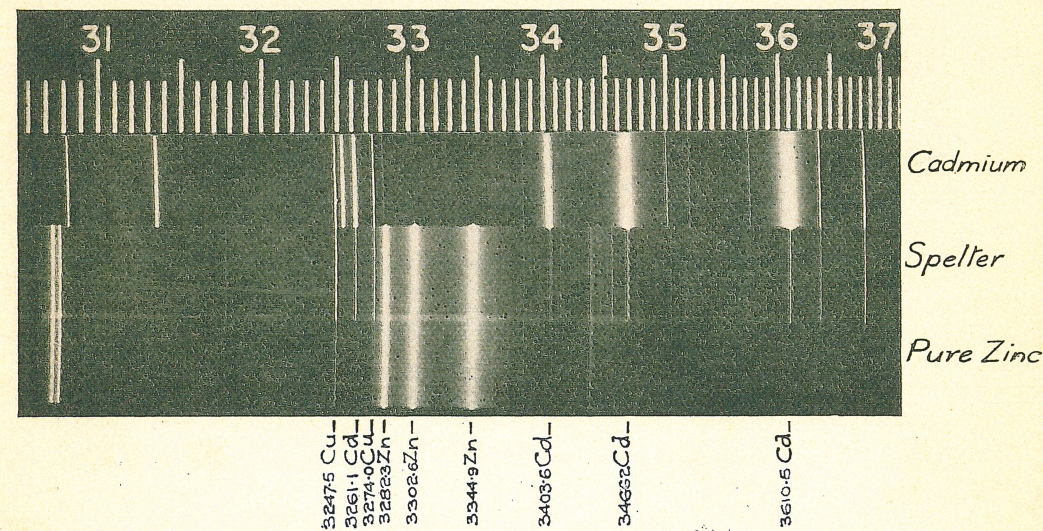


FIG. 7

slide or shutter, take a spectrogram of the metal whose presence or absence is to be determined.

It should be remembered that the top aperture of the Hartmann diaphragm corresponds with bottom spectrum.

If examinations for the presence of other metals require to be made on the same fragment, or if other metals are to be tested, the same plate can be used by racking the dark slide into a different position. Each set of spectra will be similar to Fig. 7 after development. This figure shows the determination of the presence of cadmium in spelter, though the spectra would be very similar for the determination of cadmium in sphalerite. The sensitive cadmium lines, 3261.1, 3403.6, 3466.2 and 3610.5 are seen to be present in the spectrum of the spelter, thus demonstrating the presence of cadmium in that metal. The two lines 3247.5 and 3274.0 which appear in all these spectra are the *raies ultimes* of copper, showing that even the supposedly pure zinc is not free from a small

quantity of this impurity. Lead is present in both the cadmium and the spelter, but not in the pure zinc, as shown by the lines 3683.5 and 3639.6. A small quantity of silver is present in all three samples: the line 3382.9 appears faintly in the three spectra, but the line 3280.7 which is present in the spectrum of the cadmium is masked by the strong zinc line 3282.3 in the two zinc spectra.

Among the examples of such a search for a given element may be quoted the work of Scutt (1926), and the more extensive investigations of Papish (1928-9) into the distribution of germanium in the mineral kingdom. Lacroix and de Gramont investigated the distribution of aluminium (1913) and boron (1919-21) in minerals. The former workers used the arc: the latter used the method of "fused salts" described by de Gramont (1895). Other examples are quoted in Section X.

Special methods have been used by investigators for particular purposes. Thus Lockyer (1895) and Deslandres (1895) passed the minute amount of gas evolved on heating various minerals of the uraninite group into a vacuum tube, and demonstrated the presence of helium. Misciattelli (1929) used the absorption spectrum of the rare-earth fraction from a specimen of pyromorphite to demonstrate the presence of neodymium.

(b) *Examining a mineral to determine all the metals present.*—This is difficult to carry out with a visual instrument, but it can be accomplished by extension of the method for individual metals. By this means the mineral is tested successively for all the possible metals.

With a photographic instrument, four methods of procedure are available:—

- (i) Determination of the wavelengths of all the lines present.
- (ii) Comparison with a set of standard spectra.
- (iii) Use of the R.U. Powder.
- (iv) By inspection.

Of these methods, (i) is the most general method, and can always be used. (ii) requires a considerable amount of preliminary work, but saves time if a large number of specimens of the same mineral are to be dealt with. (iii) is the most rapid, and is applicable to the recognition of all the metals excepting the rare-earth group and some other very rare metals. Method (iv) requires considerable experience of spectrum analysis, but when this has been acquired it assists the speedy recognition of the dominant elements of the mineral, and consequently leads to rapid identification of species.

METHOD 1.—A set of photographs is taken as described above, the top spectrum (obtained through the bottom aperture of the Hartmann diaphragm) being iron for the large spectrograph and copper for the medium one.

The wavelengths of each unknown line must then be measured in the following way :—¹

Choose two neighbouring iron lines, A of smaller wavelength and B of greater wavelength, lying on either side of the unknown line C, and the nearer the better. Such lines are shown in Fig. 8. Ascertain the wavelengths of the iron lines A and B by reference to the enlargement of the iron spectrum.

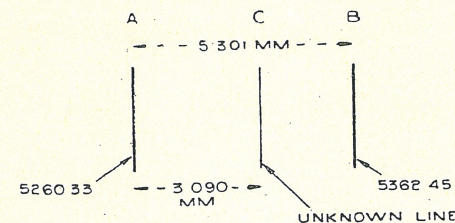


FIG. 8

Now measure on a micrometer the distances AB and AC. Suppose these distances are 5.301 and 3.090 mm. respectively, then the wavelength of the unknown line

$$= 5260.33 + (5362.45 - 5260.33) \cdot \frac{3.090}{5.301} = 5319.86.$$

The wavelength found for C will, of course, be on the same scale (*e.g.*, Rowland or International) as that in which the wavelengths for A and B are given. All modern measurements are in the international scale.

Having found the wavelengths of a number of unknown lines in this way, reference to "Wavelength Tables for Spectrum Analysis"² will enable the corresponding metals to be identified.

Having determined one or more of the constituents, a second photograph can be taken in which the bottom spectrum is that of the constituents thus found, and further search made for lines which are still present in the sample and not in the comparison spectrum.

METHOD 2.—A general method of determination is to prepare a series

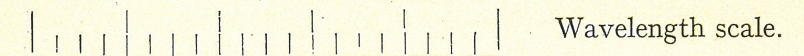
¹The method of linear interpolation here described is only applicable over very narrow ranges. Thus the distance of the reference lines from the unknown line must not exceed the following if the full accuracy of a large quartz spectrograph is to be attained :—

At	Max. permissible distance of reference lines.
6000 Å	20 Å
3000 Å	10 Å
2100 Å	3 Å

Should there be no reference lines sufficiently close, the Hartmann interpolation formula should be used as described in "The Practice of Spectrum Analysis." Published by Adam Hilger Ltd., London, Eng.

² Twyman and Smith, 2nd edition 1931. Published by Adam Hilger Ltd., London, 7s. 6d. net. 7s. 9d. post free.

of standard slides on which an electrode of constant kind is used, arranging the spectrograms and using them as follows :—



Wavelength scale.

Spectrogram of the electrodes alone, *e.g.* iron.

Composite Spectrogram of the electrodes and the selected metal.

First, one must decide with what kind of electrodes one will work: carbon, iron, copper or silver; and then prepare a spectrogram as figured for each metal selected for inclusion in the series, *i.e.*, all those likely to be found in the minerals to be examined.

Using the micrometer, one selects any unknown line in the spectrum under study, and by the wavelength scale ascertains its wavelength approximately. It is found, for example, that it is in the neighbourhood of 3965 and that another unknown line of similar strength occurs near 3930. Reference to the tables will suggest the calcium lines 3968.48 and 3933.67 as the most probable. By the micrometer it is found that the first unknown line is say 1.057 mm. from the 3977.746 iron line, if iron electrodes are used, and that the second line is 3.734 mm. from the same iron line. On comparing this with the calcium standard, identical measurements will be observed, whence the lines and the element are identified. In the event of the speculation as to the element concerned being wrong, the effort has not been wasted, for from the differences in the micrometer readings one will get at once a close indication of the true wavelengths.

METHOD 3.—It will be seen that the method of comparison spectra, described for the determination of the presence or absence of a particular metal, obviates entirely the measurement of wavelengths. This could be extended to cover several components of a mineral, but it is obvious that it would be inconvenient to analyse thus a complex mineral, because a large number of spectra would have to be photographed.

Now it is not necessary to have for comparison the complete spectrum of an element in order to identify it in the sample. All that is essential is that the comparison should show the most important sensitive lines of the element, since if these are absent in the spectrum of the sample, the corresponding element must also be absent. The ideal comparison spectrum would thus be one in which the sensitive lines of each element appear, provided the number due to each element is sufficiently few to prevent confusion, and large enough to allow confirmations to be made. Such a comparison spectrum can now be obtained readily by the use of R.U. powder.

This powder consists of small quantities of 50 elements incorporated in a base material composed of zinc, magnesium and calcium oxides. The quantity of each element present has been adjusted so that only the *raies ultimes* and the most important sensitive lines appear when the spectrum is excited by placing some of the powder in the ordinary electric arc. On the average, about seven lines per element appear, which are recognized by reference to enlargements of the spectrum of the R.U. powder, while an approximate idea of the quantity present can be obtained from a set of tables issued with the R.U. powder.

METHOD 4.—A fourth means of identifying the metals present in the spectrum of a mineral is by mere inspection. It is found with a little experience that there are groups of lines highly characteristic of certain metals; these become familiar and are recognized at a glance.

These methods have been used by a number of workers, notably by de Gramont, who not only made use of them for complete qualitative analyses of minerals whose identity was known, but also for identifying minerals. Hartley and Ramage also investigated the composition of a number of minerals and rocks with great thoroughness.

Todd (1924) describes the identification of minerals by means of a spectrographic analysis.

IV. Quantitative Analysis of Minerals.

The methods previously described are essentially qualitative, in that there is no definite measure of the quantity of each metal present. The method of search for a particular element described on p. 15 can, however, be made approximately quantitative by standardisation with minerals of known composition. The procedure is identical with that of Hartley (1884), and Pollok and Leonard, who continued his work. The method is, briefly, to take spectrograms of analysed specimens of minerals, under standardised conditions, and preserve them for reference. When another specimen is required to be analysed, its spectrum is photographed under the same standardised conditions, and the intensities of the lines of the metals to be estimated compared with corresponding lines in the spectra of the minerals whose composition is known.

This method has recently been used with great success by Schneiderhöhn. His procedure for obtaining a perfectly pure sample of mineral for analysis was to drill out shavings from highly polished sections with a very fine dental drill, the operation being observed under the microscope, to avoid drilling into the neighbouring minerals. The shavings were united with a little Plastolin, and transferred to a carbon arc. As a result of his observations, Schneiderhöhn was able to formulate a theory as to the origin of the platinum deposits of the Bushveldt Complex.

De Gramont has done similar work, in particular with the estimation of silver in lead minerals. Thus he was able to show that a specimen of zorgite¹ contained between 0.2% and 0.5% of silver.

Other work on this subject is that of Hartley (1884), who estimated copper in pyrite, and calcium and magnesium in calcite: Jolibois and Bossnet (1925) determined the gold content of minerals by means of a spectrographic assay of the lead button arising in the course of the usual fire assay. Fesefeldt (1929) described the method of determining beryllium in aluminium minerals.

A summary of the work of Hartley, Pollok, Leonard, and de Gramont will be found in "Wavelength Tables for Spectrum Analysis."²

V. Analysis of Mineral Concentrates.

This important commercial application of spectrum analysis has as yet received little attention, although the methods have been more widely employed for metals and other metallurgical products. Some work has recently been done on the subject by Dr. C. S. Hitchen and the writer.³

There is a little earlier work on the subject: Hartley, for instance, was able to carry out copper assays with considerable accuracy, but found the method more cumbersome than the chemical routine for that particular metal. Qualitative work has been carried out more frequently, e.g., analyses of ironstones by Hartley and Ramage, and an examination of bauxites for vanadium and titanium by de Gramont, though such tests are not of any very great importance from the commercial standpoint.

Some quantitative analysis of mineral concentrates has been carried out by Dr. C. S. Hitchen⁴ and the writer, using the logarithmic wedge sector described by Twyman and Simeon.⁵ The method has been more completely developed for steels by Twyman and Fitch,⁶ while further work by Hitchen on mineral concentrates will shortly be published.

¹ Since shown to be a mixture of clausenthalite, and umangite, with smaller amounts of tiemannite. G. Frebold, *Centr. Min. Geol. u. Pal.*, Abt. A., 1927, p. 16.

² Published by Adam Hilger Ltd.

³ A. A. Fitch, "Spectrum Analysis in Assaying," *Mining Magazine*, Vol. 43, p. 81, 1930.

⁴ C. S. Hitchen, "The Analysis of Wolfram and Scheelite," *Mining Magazine*, Vol. 43, p. 208, 1930.

⁵ F. Twyman and F. Simeon, "The Logarithmic Wedge Sector and its Use in Quantitative Spectrum Analysis," *Transactions of the Optical Society*, Vol. 31, p. 169, 1930.

⁶ F. Twyman and A. A. Fitch, "The Quantitative Analysis of Steels by Spectrum Analysis," *Journal of the Iron and Steel Institute*, p. 1, 1930.

VI. Analysis of Rocks.

The several methods which have been described in previous sections can all be applied to the analysis of rocks. There arises, however, a difficulty which is far more pronounced when dealing with rocks than when analysing minerals, namely, sampling. In most of the methods which have been detailed, a few milligrams at the most are volatilised. Many rocks require that the sample collected in the field shall be of several pounds weight to be truly representative: to reduce this to the minute weight required for spectrographic analysis would necessitate a long process of pulverisation and sampling. Failing this, the only method of quantitative analysis which is likely to be applied to rocks is the method of analysing solutions. No quantitative rock analyses have yet been made by this means, to the knowledge of the writer.

Precise sampling is not so necessary in qualitative work, and several rocks have been analysed spectrographically. Thus, Hartley and Ramage investigated the minor constituents of a number of ironstones and other rocks: de Gramont examined a number of laterites for vanadium and titanium. This search for a particular element is the type of rock analysis which has most often been attempted by spectrographic means.

The most complete rock analysis accomplished using spectrum analysis is one by Porlezza and Donati of a tuff from Fiuggi. The several fractions arising in the course of a very complete chemical analysis were subjected to the arc, and their spectra photographed.

VII. Analysis of Meteorites.

Analyses of the aerolites (stony meteorites) can be carried out with the same technique as that used for rock analyses, but all the work hitherto has been qualitative. The best set of analyses is that of Crookes, who developed a special technique. The meteorite was ground to powder, mixed with pure silver powder and pressed into hard electrodes. Arc spectra of these electrodes were photographed, and the composition determined from the spectrograms.

Other analyses, though not with the same method, have been made by Pereira-Forjaz and Risco.

A special type of analysis was carried out by Goldschmidt, using an X-ray method which is peculiarly suited to the determination of the rarer elements in complex bodies, owing to the small number of lines contributed by each element.

VIII. Analysis of Mineral Waters.

The spectrum analysis method of analysing mineral waters was exploited by Bunsen and Kirchhoff in their early work which resulted in the

discovery of rubidium and caesium, but since their time little work has been done on the subject.

Judd Lewis (1920) has made spectrographic analyses of mineral waters in conjunction with chemical work on them.

Pereira-Forjaz (1928-9) examined a number of Portuguese mineral waters, paying particular attention to their radio-active content. He took spark spectra of the concentrated liquor, having first, in some cases, removed the alkaline earth metals.

Friend carried out some specialised investigations on Dead Sea water, to test for the presence of "eka-caesium" and "eka-chlorine." They were found to be absent.

IX. X-ray Spectrum Analysis of Minerals.

The description of the apparatus and methods of X-ray spectrum analysis are not treated of here and reference should be made to the papers listed in the bibliography.

The analysis referred to is not the X-ray analysis of crystal structure as practised by Bragg and others, but the qualitative and quantitative analysis by means of X-ray spectrum analysis, in the development of which, and the application of the method to mineral analysis, Hadding has played a considerable part.

Further investigations by the following writers, using X-rays, are included in the bibliography:—

Siegbahn, Lindh and StenSSon.

Wild and Klemm.

Zvjaginstsev, Korsunski and Seljakow.

Bedr-chan.

Thomassen.

Eddy, Laby and Turner.

X. Mineral determination by means of absorption spectra.

All the methods of spectrum analysis hitherto described have been based upon various types of emission spectra. There remain to be considered those methods involving the use of absorption spectra.

Absorption spectra can be used with the ordinary type of spectroscopic or spectrograph. The procedure is to pass a beam of white light through a plate of the mineral and so on to the slit. The position of the absorption bands can then be determined by visual or photographic means, and the presence of particular elements deduced therefrom, with the help of tables of the type given by Wherry. Such absorption work has been carried out by Becquerel and others using large spectrographs. Misciatelli examined

the absorption spectra of solutions obtained during the course of a mineral analysis, and concluded that particular elements were present: generally speaking, however, it may be concluded that examination of such solutions would best be carried out using emission spectra. Reference to recent work on this subject by Weigel and Habich and Weigel and Ufer will be found in the bibliography.

The type of spectrum analysis most familiar to the mineralogist is probably that carried out with the spectroscopic eyepiece, or micro-spectroscope. This is merely a low-dispersion, direct-vision spectroscope which is inserted in the microscope in the place of the eyepiece, and only resolves the more prominent of the bands. The method is quite widely used for the recognition of cerium in monazite and related minerals, but with the help of the tables given by Wherry, the method could be applied much more frequently.

XI. Examples of minerals which have been spectroscopically analysed.

(The numbers refer to the bibliography.)

I. NATIVE ELEMENTS.

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Native copper	- Butte, Montana	Ge	53
"	- Mednorudyansk, Ural, nr. Nizhne Tagilsk	Ge	53
"	- Merrit, British Columbia	Ge	53
"	- Bisbee, Arizona	Ge	53
"	- Globe Arizona	Ge	53
"	- Somerville, New Jersey	Ge	53
"	- Lake Linden, Michigan	Ge	53
Native Platinum	- Columbia	Pt Fe Pd Rh Ir Os 27 & 28 Ru	
"	- Gorablogodatski region, Ural	Absence of dwi- manganese	78

II. SULPHIDES, SELENIDES, TELLURIDES, ARSENIDES, ANTIMONIDES.

Galena	- - -	S Ag Pb Cu Sn Fe Ca Mg Sb Bi	16
"	- - -	Egham, Derbyshire Ca	31
"	- - -	Derbyshire Ca	31
"	- - -	Johanngeorgenstadt, Saxony Mn	31

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Galena	- - -	Friberg, Saxony K Na Cu Ag Fe Pb Mn	31
"	- - -	Ratiborcitz, Saxony K Na Cu Ag Fe Pb Mn	31
"	- - -	Schemnitz Selmezbanya, Bohemia K Na Cu Ag Fe Pb Mn	31
"	- - -	Gersdorf K Na Cu Ag Fe Pb	31
"	- - -	Nertschinsk, Siberia K Na Cu Ag Fe Pb Ca	31
"	- - -	— Pb	4
Argyrite	- - -	— S Ag Cu Sn Fe Ca Mg Pb Zn	16
Zorgite	- - -	— 0.2%–0.5% Ag	17
Sphalerite	- - -	Cornwall Cd In Ga Th	65
"	- - -	Cumberland Cd In Ga Th	65
"	- - -	Derbyshire Cd In Ga Th	65
"	- - -	Devil's Bridge, Aberystwith Ge	65
"	- - -	Picos de Europa, Santander Zn S Al Ag Ca	15
"	- - -	Pierrefitte, Hautes Pyrenees Na K Ag Cu Zn Fe Ga Pb Ca Cd	31
"	- - -	Lüderich Mine, Adit Franziska, Bensburg, nr. Cologne Na K Ag Cu Zn Fe Ga Pb Ca Cd	31
"	- - -	Santander, Spain Na K Ag Cu Zn Fe Ga Pb Ca Cd In	31
"	- - -	Alston Moor, Cumberland Na K Ag Cu Zn Fe Ga Pb Ca Cd In Th	31
"	- - -	Silver Mines, Co. Tipperary, Ireland Na K Ag Cu Zn Fe Ga Pb In Ni Cr	31
"	- - -	Zellerfeld, Saxony Na K Ag Cu Zn Fe Ga Pb Ca Cd	31
"	- - -	Schemnitz, Hungary Na K Ag Cu Zn Fe Ga Pb	31
"	- - -	Matlock, Derbyshire Na K Ag Cu Zn Fe Ga Pb Ca Cd Th	31
"	- - -	— Na K Ag Cu Zn Fe Ga Pb Cd In	31
"	- - -	Co. Tipperary Ireland Na K Ag Cu Zn Fe Ga Pb In Th	31
"	- - -	La Cabada Mine, Rio Tinto, Spain Na K Ag Cu Zn Fe Ga Ca Ni	31

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Sphalarite -	Laxay, Isle of Man	Na K Ag Cu Zn Fe	31
		Ga Pb In	
" -	Freiberg, Saxony	Na K Ag Cu Zn Fe	31
		Pb In	
" -	Ravenswood, Queens- land, Australia	Na K Ag Cu Zn Fe	31
		Pb Ca In	
Pentlandite -	Zwartfontein	Fe Co Ni Cu Pa Ir	64
		Sb Ag Au	
Greenockite -	—	V Fe Co Ni Ru Rh	75
		Pa Os Ir Pt Cu Cd	
Niccolite -	—	K Na Cu Ca Fe Ni	31
		Mn Pb Ag Co Ba Sr	
Pyrrhotite -	Norway	K Na Cu Ca Fe Ni	31
		Mn Pb	
" -	Rom., Smalleneul, Norway	Na K Ag Cu Ca Fe	31
		Ni Mn	
" -	Anroen, Bamle, Norway	Na K Ag Cu Ca Fe	31
		V Fe Co Ni Ru Rh	64
		Pd Os Ir Pt	
" -	—	V Fe Co Ni Ru Rh	64
		Pd Os Ir Pt Cu Au	
Cubanite -	Zwartfontein	V Fe Cu	64
Chalcopyrite -	—	Na K Ag Cu Ca Fe	31
		In Th Ni Pb	
" -	—	Fe Co Ni	64
" -	Zermatt	K Li	4
" -	Serpentines du Geiss- pfad, Binnenthal	K Li	4
Pyrites -	Wheal Lane, Cornwall	Na K Ag Cu Ca Fe	31
		In Th Mn Pb	
" -	Esna, Norway	Na K Ag Cu Ca Fe	31
		Ga In Mn Pb	
" -	Staffordshire	Na K Ag Cu Ca Fe	31
		Th Mn Ni Pb	
" -	Roschau	Na K Ag Cu Ca Fe	31
		Mn Pb	
" -	Freiberg, Saxony	Na K Ag Cu Ca Fe	31
		In Pb	
" -	Schemnitz, Selmech- banya, Hungary	Na K Ag Cu Ca Fe	31
		Mn Pb	
" -	Isle of Elba	Na K Ag Cu Ca Fe	31
		Mn Pb	

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Pyrites -	Goslar, Hartz	Na K Ag Cu Ca Fe	31
		Th Mn Pb	
" -	Joachimsthal, Bohemia	Na K Ag Cu Ca Fe	31
		Pb	
" -	—	K Li	4
Marcasite -	Dover	Na K Ag Cu Ca Fe	31
		Th Ni Mn	
Smaltite -	—	K Na Cu Ca Fe Mn	31
		Ni Pb Ag Co	
Sperrylite -	Twefontein, Potgietersrust	Rh Pd Ir Pt Ag Au	64
Cooperite -	Klipfontein-Kroondal Mine, Rustenberg	Rh Pd Ir Pt Ag Au	64
Stibiopalladinite -	Twefontein, Potgietersrust	Rh Pd Ir Pt Sb Ag Au	64
III. SULPHOSALTS.			
Sartorite -	—	As Ag Tl	11
" -	—	Tl	4
Hutchinsonite -	—	Tl	4
" -	—	Tl	11
Baumhauerite -	—	Pb As	11
Dufrenoyite -	—	Pb Tl	4
Pyrargyrite -	Colquechaca, Dept. Potosi, Bolivia	Ge	53
" -	"	Ge absent	53
Binnite -	—	Tl	4
Jordanite -	—	Pb Tl	4
Stannite -	Itos Mine, Oruro, Bolivia	Ge	53
" -	Santo Cristo Mine, Oruro, Bolivia	Ge	53
" -	Zeekan, Tasmania	Ge	53
" -	Cornwall, England	Ge	53
IV. HALOIDS.			
Rock Salt -	Stassfurt	Na K Fe	32
Sylvite -	Stassfurt	Na K Fe	32
Fluorite -	Amelia, Virginia	Y Sm Er	75
Fluocerite -	Osterby	Ce Pr Nd Sm Gd Er	27
		Dy Cu Y	
" -	—	Nd Pr	75
Cryolite -	—	Al	19

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Cryolite - -	Arsuk, Greenland	Na Al Li Si Mg Ca	15
Tachhydrite - -	Stassfurt	Na K Fe Sr Mn	32
V. OXIDES OF SILICON.			
Vein quartz - -	Silver Leaf Mine, Manitoba	Ge absent	54
" - -	Rutherford, Maine	Ge absent	54
" - -	Keystone, South Dakota	Ge absent	54
Quartz - -	—	Na K Cu Ca Fe Mn Pb	35
" - -	—	Li	4
Amethyst - -	Mont Blanc	Li	4
" - -	—	Cr Fe Ti	75
" - -	—	Fe Co Ti	75
" - -	—	Fe Co	75
Rose quartz - -	—	Mn	38
" - -	—	Mn	75
Smoky quartz - -	Uri, Switzerland	Ge absent	54
Chalcedony - -	—	Ge absent	54
Opal - -	—	Ge absent	54
" - -	—	Ge absent	54
VI. ANHYDROUS OXIDES OF THE METALS.			
Cuprite - -	—	Cu	75
Manganosite - -	—	V Mn	75
Corundum - -	—	B absent	46
" - -	—	B absent	45
" - -	—	Na K Ag Ga Fe	35
" - -	—	Na K Cu Ag Ca Ga Fe Cr	35
" - -	—	Cr	75
" - -	—	Fe	75
Sapphire - -	Anakia	Fe Ti	77
" - -	Ceylon	B Al Fe Ge	77
" - -	—	Ti	75
Ruby - -	—	Na K Cu Ag Ca Ga Fe Mn Cr	35
Haematite - -	Cleator Moor, Cumber- land	K Na Cu Ag Fe	31
" - -	Antwerp, New York, U.S.A.	K Na Cu Ag Fe	31
" - -	Elba	K Na Cu Ag Fe	31

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Haematite - -	Canada	K Na Cu Ag Fe	31
" - -	Osnaberg, Germany	Na K Mn Ca Pb In	31
" - -	Haycock Mine, Ontario	Na K Mn Ca Pb	31
" - -	Esvenstock, Saxony	Na K Mn	31
" - -	Altenberg, Saxony	Na K Mn Ca In	31
" - -	Schwarzenberg, Erzgebirge	Na K Mn Ca Ga Th In Rb	31
" - -	Schwarzenberg, Erzgebirge	Na K Mn Ca Ga Ni	31
" - -	Schneeberg, Saxony	Na K Mn	31
" - -	Elba	Na K Mn Ca	31
" - -	Norberg, Sweden	Na K Mn Ca	31
" - -	Styria	Na K Mn Ca Pb	31
" - -	nr. Llantrissant, Wales	Na K Mn Ca Pb Rb	31
" - -	—	Na K Mn Ca Pb	31
" - -	Darlkarsberg, Sweden	Na K Mn Ca Pb Ga	31
" - -	Mossaberg, Sweden	Na K Mn Ca Pb Rb	31
" - -	Uri	Fe Li	4
" - -	Binnenthal	Fe Li	4
Spinel - -	—	Na K Cu Ag Mg Ga Fe Cr	35
" - -	—	Mn	75
" - -	—	Fe	75
" - -	—	Co Ti	75
" - -	—	Cr Fe Co Ti	75
Magnetite - -	Moriah Mine, Essex Co., N.Y.	Na K Ag Cu Ca Ga Mn Fe Rb	31
" - -	Ozarka Mountains, Arkansas	Na K Ag Cu Ca Ga Mn Fe Pb	31
" - -	Opdal Skage, Namsa, Norway	Na K Ag Cu Ca Ga Mn Fe Pb Ni	31
" - -	Darlkarsberg, Sweden	Na K Ag Cu Ca Ga Mn Fe Pb Rb	31
" - -	Bispberg, Sweden	Na K Ag Cu Ca Ga Mn Fe Pb Rb	31
" - -	Dannemora, Sweden	Na K Ag Cu Ca Ga Mn Fe Pb Rb In	31
" - -	Zermatt	Fe Li	4
" - -	Serpentines du Geisspfad, Binnenthal	Fe Cr	4
" - -	Rympfischwänge, Zermatt	Li	4

<i>Mineral</i>		<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Magnetite	-	-	Geisspfad	Li 4
"	-	-	Dalerna	Fe Cu Zn 27 & 28
Franklinite	-	-	New Jersey	Mn Fe Cu Zn 27 & 28
Jacobsite	-	-	—	Fe & Cr absent 4
Chromite	-	-	Serpentines du Geisspfad	Fe Cr 4
"	-	-	—	V Fe Co Ni 4
"	-	-	Baltimore	Cr Fe Ni Cu 27 & 28
				W Zn
Cassiterite	-	-	—	Na In Fe Sn Pb 31
"	-	-	Camborne, Cornwall	Na In Fe Sn Cu Ca 31
"	-	-	Ehrenfriedsorf, Saxony	Mn
"	-	-	St. Agnes, Cornwall	Na In Fe Sn 31
				Na In Fe Sn Ag Cu 31
				Ca Mn Rb
Rutile	-	-	—	Na K Cu Ca Fe Mn 35
				Pb
Pyrolusite	-	-	Giessen, Saxony	Na K Cu Ca Fe Mn 31
				Rb Ni Ag
"	-	-	Ilmenau, Thuringia	Na K Cu Ca Fe Mn 31
				Rb Th Ag
"	-	-	—	Na K Cu Ca Fe Mn 31
				Rb Ga Th Ag
"	-	-	Franklin Furnace	Na K Cu Ca Fe Mn 31
				Ni

VII. HYDROUS OXIDES OF THE METALS.

Diaspore	-	-	—	B absent 46
"	-	-	—	B absent 45
Manganite	-	-	—	Na K Cu Ca Fe Mn 31
				Ga Ni Ag
"	-	-	—	Na K Cu Ca Fe Mn 31
				Ga Th Pb Sr Ba Ag
"	-	-	Sargans	Fe Mn 4
Limonite	-	-	—	Na K Rb Ag Fe Mn 31
				Cu Ca Pb Ni Th Cr
"	-	-	Langenstrieges, Saxony	Na K Rb Ag Fe Mn 31
				Cu Ca Pb Ni
Limonite	-	-	Lercoul, Arriège, France	Na K Rb Ag Fe Mn 31
				Ca
"	-	-	Fleetwood, Pennsylvania, U.S.A.	Na K Rb Ag Fe Mn 31
				Pb

<i>Mineral</i>		<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Bauxite	-	-	—	K Na Cu Ca Ga Fe 31
				Ni Cr Ag
"	-	-	Co. Antrim, Ireland	K Na Cu Ca Ga Fe 31
				Ni Mn Cr
"	-	-	—	K Na Cu Ca Ga Fe 31
				Mn Cr Ag
"	-	-	Arles, France	K Na Cu Ca Ga Fe 31
				Ni Cr Ag
"	-	-	Arles, France	K Na Cu Ca Ga Fe 31
				Ni Cr Ag
"	-	-	—	K Na Ca Ga Fe Ni 31
				Mn Cr
"	-	-	Arles	K Na Ca Ga Fe Ni 31
				Mn Cr
"	-	-	Arles	K Na Ca Ga Fe Ni 31
				Mn Cr
"	-	-	North of Ireland	K Na Ca Ga Fe Ni 31
				Mn Cr
"	-	-	Arles	K Na Ca Ga Fe Ni 31
				Mn Cr
"	-	-	Ireland	Cu 32
"	-	-	Var	Fe V 24
Hydrargyllite	-	-	—	B absent 46
"	-	-	—	B absent 45
Psilomelane	-	-	nr. Dolgelly, N. Wales	Na K Cu Ca Fe Mn 31
				Ga Ni Ag
"	-	-	Lorca, Spain	Na K Cu Ca Fe Mn 31
				Rb Ga Sr Ba Ag
"	-	-	Siegen, Westphalia	Na K Cu Ca Fe Mn 31
				Rb Ni Sr Ag

VIII. CARBONATES.

Calcite	-	-	Pont de Bonieux, Near Saint Jean de Maurienne	Mg Sr 15
"	-	-	Saleve	Sr 4
"	-	-	Meillerie	Sr 4
"	-	-	—	1% Mg 37% Ca 29
"	-	-	Joplin, Missouri	Nd 75
Dolomite	-	-	—	Ca Mg 3
"	-	-	—	Sr 4

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Siderite	- - East Pool, Cornwall	Na K Ag Cu Ca In Mn Rb Pb	31
„	- - East Pool, Camborne, Cornwall	Na K Ag Cu Ca In Mn Co Ni Bi	31
„	- - West Cornwall	Na K Ag Cu Ca In Mn Pb	31
„	- - Hendaye, Spain	Na K Ag Cu Ca In Mn Pb	31
„	- - Siegen, Westphalia	Na K Ag Cu Ca In Mn	31
Rhodochrosite	- - —	Mn	75
Strontianite	- - —	Nd	75
Parisite	- - —	“ Dy ”	2
Cordylite	- - —	Nd Pr	75
Bastnaeite	- - —	Nd	75
Azurite	- - —	Cu	75
Lanthanite	- - —	Nd Pr	75
Liebigite	- - —	U	75
Uranothallite	- - —	U	75
Voglite	- - —	U	75

IX. DISILICATES AND POLYSILICATES.

Petalite	- - Utö, Sweden	Li Si Al Ca Rb	15
Felspar	- - —	Li Na K Rb Cs Cu Ca Al Ga Fe Mn Pb	35
Orthoclase	- - Winter Harbour, Cum- berland Sound	Ge	54
„	- - Fuchsbach, Silesia	Ge	54
„	- - Brevig, Norway	Ge	54
„	- - Herschell, Ontario	Ge	54
„	- - Jones Falls Quarry, Baltimore, Md.	Ge	54
„	- - Robinson, Colorado	Ge	54
„	- - Pike's Peak, Colorado	Ge	54
„	- - Pacific Grove, California	Ge	54
„	- - Itrongahy	B absent	45
„	- - —	B absent	46
„	- - Ceylon	Little Al in spectrum	19
„	- - Saint Gothard, Grisons	Al	15
„ (adularia)	- - —		
„ (cassinite)	- Blue Hill, Penn.	Si Ba	15

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Orthoclase	- - —	Li Na K Rb Cu Ca Fe Mn Pb	35
„ (moonstone)	- - —	Cu	26
„	- - Viesch	Li	4
„	- - Kriegalp	Li	4
„	- - Dammastock	Li	4
„	- - Fellithal	Li	4
Microlite	- - Verona, Ontario	Ge	54
„	- - Bathurst, Ontario	Ge	54
„	- - Villeneuve, Quebec	Ge	54
„	- - Bedford, New York	Ge	54
„	- - Amelia Court House, Va.	Ge	54
„	- - El Paso County, Colo.	Ge	54
„	- - Keystone, South Dakota	Ge	54
„	- - nr. Nain, Labrador	Ge	54
„	- - Maharita, Madagascar	Al	19
„	- - Antaboaka, Madagascar	Al	19
„	- - Dalkey, Co. Dublin	Na K Li Rb	30
„	- - Madagascar	Rb Cs Ga Fe	26
„	- - Madagascar	Rb Cs Ga Th	18
„	- - Anjanambonoina	Cs Rb Ga Th	25
„	- - Manjaka	Cs Rb Ga Th	25
„	- - Antaboaka	Cs Rb Ga	25
„	- - Antsongombato	Cs Rb Th	25
„	- - Maharitra	Cs Rb	25
„	- - Tsilaizina	Rb Ga	25
Anorthoclase	- - —	Na Li	4
Albite	- - Alpe Ruschuna, near Vals, Switzerland	Ge	54
„	- - Silver Leaf Mine, Mani- toba	Ge	54
„	- - Amelia Court House, Va.	Ge	54
„	- - Amelia Court House, Va.	Ge	54
„	- - Keene, New Hampshire	Ge	54
„	- - Norway, Maine	Ge	54
„	- - Keystone, S.D.	Ge	54
Albite	- - De Modana	Si Na Al Ca Mg	15
„ (peristerite)	- Villeneuve, Canada	Ca	15
Oligoclase	- - Siberia	Ge	54
„	- - Arendal, Norway	Ge	54
„	- - Gilbertville, Mass.	Ge	54
„	- - Orange County, N.Y.	Ge	54

<i>Mineral</i>		<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Oligoclase	-	Anthony's Nose, near Peekskill, N.Y.	Ge	54
"	-	Media, Pa.	Ge	54
"	-	Virginia	Ge	54
Andesine	-	Cape Keglapait, Labrador	Ge	54
"	-	Bodenmais, Bavaria	Ge	54
"	-	Bodenmais, Bavaria	Ge	54
"	-	St. Raphael, France	Ge	54
"	-	Palmietfontein, Zontpansberg, Transvaal	Ge	54
Oligoclase	-	Bakersville, N.C.	Na Si Al Ca	15
"	-	Ytterby, Sweden	Si Ca	15
Labradorite	-	nr. Nain, Labrador	Ge	54
"	-	nr. Sarnac Junction, N.Y.	Ge	54
"	-	Aci Trezzo, Cyclopean Islands, Italy	Ge absent	54
"	-	Mount Etna, Italy	Ge	54
"	-	Millard County, Utah	Ge	54
"	-	Coast of Labrador	Si Ca Na Al	15
Bytownite	-	Bytown, Canada	Ge	54
"	-	Crystal Bay, Minnesota	Ge	54
Anorthite	-	Pesmed, Fassathal, Tyrol	Ge	54
"	-	Mount Somma, Naples	Ge	54
"	-	Miakejima, Japan	Ge	54
"	-	Somma	Si Al Na Mg	15
"	-	New Caledonia	Si Al Na Mg	15

X. LEUCITE GROUP.

Leucite	-	Ciriocia, Italy	Ge	54
"	-	Vesuvius	Ge	54
"	-	Frascati, Rome, Italy	Ge	54
"	-	Capo di Bovi, near Rome, Italy	Ge	54
"	-	Civita Castellana, Latium, Italy		
"	-	Pompeii, Italy	Ge	54
Pollucite	-	Island of Elba	Ge	54
"	-	Buckfield, Maine	Ge	54

<i>Mineral</i>		<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Pollucite	-	Black Hill, S.D.	Ge	54
"	-	—	B absent	45
"	-	—	B absent	46
"	-	—	Cs Li Si Al Ca	15

XI. PYROXENE GROUP.

Enstatite	-	Pelham, Mass.	Ge	54
Diopside	-	De Kalb, New York	Ge	54
"	-	Patterson, N.J.	Ge	54
"	-	Haliburton County, Ontario	Ge absent	54
"	-	Itrongahy	B absent	45
Augite	-	Buffaura, Fassathal, Piedmont	Ge	54
"	-	Fassathal, Piedmont	Ge absent	54
Spodumene	-	Halstead, New Hampshire	Ge	54
"	-	Goshen, Mass.	G.	54
"	-	Norwich, Mass.	Ge	54
"	-	Chesterfield, Mass.	Ge	54
"	-	Auburn, Maine	Ge	54
"	-	Andover, Maine	Ge	54
"	-	Oxford Co., Maine	Ge	54
"	-	nr. Paris, Maine	Ge	54
"	-	Calmilla, California	Ge	54
"	-	Minas Geraes, Brazil	Ge	54
"	-	Utö, Sweden	Ge	54
"	-	—	Co Na Sn	77
" (hiddenite)	-	—	Cr Na Sn V Mn	77
"	-	—	Cr Co Ag Ti Na Sn	77
"	-	—	V Mn Li Co	
"	-	—	Mn Co Na	77
Hiddenite	-	Hiddenite, Alexander Co., N.C.	Ge	54
"	-	—	Cr	75
Kunzite	-	Pala, California	Ge	54
"	-	Pala, California	Ge	54
"	-	Pala, California	Ge	54
"	-	Pala, California	Ge	54
"	-	—	Ga	75
Kunzite	-	—	Mn	75

<i>Mineral</i>		<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Wollastonite	-	Natural Bridge, N.Y.	Ge absent	54
"	-	Orange County, N.Y.	Ge	54
Rhodonite	-	Valles de Louron	Si Mn Al	15
		Hautes Pyrenees		
"	-	nr. Dolgelly, N. Wales	Na K Cu Ca Fe Mn	31
			Ag Ni	
"	-	Paisberg, Sweden	Na K Cu Ca Fe Mn	31
			Ag Pb	
"	-	—	Mn	75
Wöhlerite	-	—	Na	75

XII. AMPHIBOLE GROUP.

Anthophyllite	-	Copper Mine, Washington Co., Md.	? Ge	54
"	-	Kipps Bay, New York	Ge absent	54
"	-	Harford Co., Md.	? Ge	54
" amphiboles "	-	—	Ca Li	4
Tremolite	-	Amity, Orange County, N.Y.	Ge	54
"	-	Canaan, Connecticut	? Ge	54
"	-	Ossinning, New York	? Ge	54
"	-	—	Mn	75
Actinolite	-	Mineral Hill, Pa.	Ge	54
"	-	Brewsters, New York	Ge absent	54
"	-	Kent, Putnam County, N.Y.	Ge absent	54
Asbestos	-	Germany	? Ge	54
"	-	Thetford, Quebec	? Ge	54
Mountain Leather	-	Nova Scotia	Ge absent	54
Riebeckite	-	St. Peter's Dome, El Paso Co., Colo.	? Ge	54

XIII. OTHER METASILICATES.

Beryl	-	Limoges	Si Al Na Be Ca	15
"	-	Glencullen, Co. Dublin	Li Na K Rb Cs Cu	35
			Ag Ca Ga Th Fe Mn	
			Pb	
"	-	Naegi, Japan	Si Be Fe Al Ca Mg	67
			Cr Na K Sn Sc	
"	-	Ishikawa, Japan	Si Be Fe Al Ca Mg	74
			Sc	

<i>Mineral</i>		<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Beryl	-	Madagascar	Cs Ga	26
"	-	Madagascar	Cs Ga	18
"	-	Antaboaka	Cs Rb Ga Th Li Mn	25
"	-	Maharitra	Ti Sc	25
"	-	Antsongombato	Ti Sr	25
"	-	—	Ga Mn Cs	77
"	-	Brasil	Cs	77
"	-	Madagascar	Cs	77
"	-	Madagascar	Ni Cu Zn Sn Pb Li	77
			Ga Mn Na	

XIV. GARNET GROUP.

Garnet	-	Airolo, Canton Ticino	Na K Cu Ag Mg Ca	35
			Sr Ga Fe Mn Cr Pb	
Pyrope	-	—	Cr	75
Almandine	-	—	Cr	75
Spessartite	-	Saint Marcel, Piedmont	Mn Si Ca Al Na	15
"	-	—	Cr	75
Demantoid	-	—	Cr	75

XV. OLIVINE GROUP.

Olivine	-	—	Fe Co Ni	64
"	-	—	Fe	75

XVI. IDOCRASE.

Idocrase (Wiluite)	-	Wilui, Siberia	B Ti F	45
"	-	Pics de Pegneres, Hautes Pyrenees	B Ti F	45
"	-	Pic d'Arbizon	B Ti F	45
"	-	Col de Bouts, Aragon	B Ti	45
"	-	Vallee de Fleim, Tyrol	B Ti	45
"	-	Egg, Norway	B Ti F	45
"	-	Christiansand, Norway	B Ti	45
"	-	Canigou	B Ti	45
"	-	Pic du Midi du Bigorre	B Ti	45
"	-	Sahun, Aragon	B Ti	45
"	-	Pic des Posets Aragon	B Ti	45
"	-	Ala, Piedmont	B Ti F	45
"	-	Göpfersgrün, Bavaria	B Ti	45
"	-	Parsonfield, Maine	B Ti	45
"	-	Rougedas, Morbihan	Ti B absent	45
"	-	Zermatt	Ti F B absent	45

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Idocrase (Wiluite)	Cziklova, Banat	Ti F B absent	45
„ (Egerane) -	Eger, Bohemia	Ti B absent	45
„ (Frugardite) -	Mantsala, Finland	Ti B absent	45
„ (Heteromerite)	Mantsala, Finland	Ti B absent	45
„ (Jewreinowite)	Mantsala, Finland	Ti B absent	45
„ (Cyprine) -	Souland en Telemarken	Ti B absent	45
„ (Wiluite) -	—	B	46
„ (Egerane) -	—	B	46
„ (Frugardite) -	—	B	46
„ (Heteromerite)	—	B	46
„ (Jewreinowite)	—	B	46
„ (Cyprine) -	—	B	46
„ - - -	—	B absent	46
„ - - -	—	Fe	75
„ - - -	—	Fe	75

XVII. ZIRCON GROUP.

Zircon - - -	Miask, Urals	Zr Ca	15
„ - - -	Ishikawa Hill	Pb Ba Ti Y Sc Nd 43 & 44	
„ - - -	Alter Pedroso	Gd Dy Er Yt Lu	
„ - - -	—	Si Zr Ca Al Fe Th	55
„ - - -	—	Ti Mg Sn Bi Cu	
„ (Jargon) -	—	U	75
„ - - -	—	U	2
„ - - -	—	Zr	71
„ - - -	Sveneroe, Norway	“ Dy ”	2
„ - - -	Siberia	Mn	71
„ - - -	Miask	U absent	71
„ - - -	—	U	2
Naegite - -	Naegi	Ce Nd La Pr Sm Y	66
„ - - -	—	Dy Er Yt Gd Tb Ho	
Hagatalite -	Hagata	Y Sc Nd Pr Eu Dy	44
„ - - -	—	Ho Er Tl Ge Nb Ta	
Oyamalite -	Oyama	Y Nd Gd Dy Er Yt	44

XVIII. DANBURITE-TOPAZ GROUP.

Topaz - - -	Tasmania	Ge	54
„ - - -	Zinnwald, Bohemia	Ge	54
„ - - -	Zinnwald, Bohemia	Ge	54
„ - - -	Altenberg, Saxony	Ge	54
„ - - -	Altenberg, Saxony	Ge	54
„ - - -	Altenberg, Saxony	Ge	54

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Topaz - - -	Schlackenwald, Saxony	Ge	54
„ - - -	Schneckenstein, Saxony	Ge	54
„ - - -	Schneckenstein, Saxony	Ge	54
„ - - -	Brodbo, Sweden	Ge	54
„ - - -	Mursinzk, Siberia	Ge	54
„ - - -	Sanark River, Ural	Ge	54
„ - - -	Ural Mountains	Ge	54
„ - - -	Tanakami, Yama Ouir, Japan	Ge	54
„ - - -	Naegi Mino, Japan	Ge	54
„ - - -	Klein Spitzkopje, South-west Africa	Ge	54
„ - - -	New South Wales	Ge	54
„ - - -	Silver Leaf Mine, Manitoba	Ge	54
„ - - -	Nathpop, Chaffee Co., Colorado	Ge	54
„ - - -	Florissant, Colorado	Ge	54
„ - - -	Thomas Range, Millard Co., Utah	Ge	54
„ - - -	Sevier Lake, Utah	Ge	54
„ - - -	Trumbull, Conn.	Ge	54
„ - - -	Trumbull, Conn.	Ge	54
„ - - -	Easton, Conn.	Ge	54
„ - - -	Monroe, Conn.	Ge	54
„ - - -	Stoneham, Maine	Ge	54
„ - - -	Stoneham, Maine	Ge	54
„ - - -	Stoneham, Maine	Ge	54
„ - - -	San Luis, Potosi	Ge	54
„ - - -	Villa Rica, Brazil	Ge	54
„ - - -	—	B absent	46
„ - - -	—	B absent	46
„ - - -	—	Al	19
„ - - -	Schneckenstein, Saxony	Ge	52
„ - - -	Zinnwald, Bohemia	Ge	52
„ - - -	Trumbull, Connecticut	Ge	52
„ - - -	Stoneham, Maine	Ge	52
„ - - -	Florissant, Colorado	Ge	52
„ - - -	Naegi Mino, Japan	Ge	52
„ - - -	Silver Leaf Mine, Manitoba	Ge	52

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Topaz - - -	Ceylon	Cr	26
" - - -	Ouro Porto, Brasil	Cr Fe Ag Na V	77
" - - -	Ouro Porto, Brasil	Cr Ag Na V	77
" - - -	Ouro Porto, Brasil	Cr	77
" - - -	Brasil	Cr absent	77
" - - -	—	Cr	77
" - - -	—	Cr	77
" - - -	—	Cr	77
" - - -	Schneckenstein	Cr V Ag Na	77
" - - -	San Louis Potosi, Mexico	Cr absent	77
" - - -	San Louis Potosi, Mexico	Cr absent	77
" - - -	Itinga, Minas Geraes	Mg V Ag Cr Na	77
" - - -	—	Mn	75
Andalusite - -	Neualbenreuth, Bavaria	Ge	54
" - - -	Lisenvally, Tyrol	Ge	54
" - - -	Fillenberg, nr. Marienbad, Bohemia	Ge	54
" - - -	Leiparville, Pa.	Ge	54
" - - -	Lancaster, Mass.	Ge	54
" - - -	Westford, Mass.	Ge	54
" - - -	White Mountains, N.H.	Ge	54
" - - -	—	B absent	46
" - - -	—	V	75
Sillimanite - -	Norwich, Conn.	Ge	54
" - - -	Chester, Conn.	Ge	54
" - - -	Custer, South Dakota	Ge	54
" - - -	Brandywine Springs, Delaware	Ge	54
Kyanite - - -	Windham, Maine	Ge	54
" - - -	Newtown, Conn.	Ge	54
" - - -	Blandford, Mass.	Ge	54
" - - -	Moores, Pa.	Ge	54
" - - -	Chester, Pa.	Ge	54
" - - -	—	Ti B absent	54
" - - -	—	B absent	46
XIX. DATOLITE GROUP.			
Euclase - - -	—	B absent	46
Yttrialite - -	—	Hf	3

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Rowlandite - -	—	Nd	75
Alvite - - -	—	Sm Er	75
XX. EPIDOTE GROUP.			
Thulite - - -	—	Mn	75
Epidote - - -	—	Fe	75
Piedmontite - -	—	Mn	75
Allanite - - -	Ishikawa	Ce La Nd Yt Gd	43
" - - -	Hagata-Mura	Ce La Pr Nd Sm Y	49
" - - -	—	Er Tm Yb Dy Ho	
" - - -	—	Mn Zn	
" - - -	Iyo, Shikoku	Na K Mg Ca Mn Fe	63
" - - -	—	Al Y La Ce Si Sn	
" - - -	—	Ti Th Sr Cu Zn Ge	
Axinite - - -	Balme d'Auris, Oisana	Ca Si Al Mn Mg	15
" - - -	Eredlitz, Hautes Pyrenees	Ca Si Al Mn Mg	15
Prehnite (Koupholite)	Piquette deras lids	Ti B absent	45
" - - -	—	B absent	46
" (Koupholite)	—	B absent	46
XXI. SUBSILICATES.			
Ilvaite - - -	—	B absent	45
" - - -	—	B absent	46
Calamine - - -	Bleiberg, Carinthia	Ge	53
" - - -	Granby, Missouri	Ge	53
" - - -	La Duchessa, Sardinia	Ge	53
" - - -	Friedensville, Penn.	Ge	53
" - - -	Malfidano, Sardinia	Ge	53
" - - -	Sardinia	Ge	53
" - - -	Joplin, Mo.	Ge	53
" - - -	Leadville, Colo.	Ge	53
" - - -	Organ Mts., Dona Ana Co., New Mexico	Ge	53
" - - -	Matlock, Derbyshire	Ge	53
" - - -	Elkhorn, Montana	Ge	53
" - - -	Cumberland, England	Ge	53
" - - -	Sanander, Spain	Ge	53
" - - -	Ogdensberg, N.J.	Ge	53
" - - -	Wentworth, Mo.	Ge	53
Tourmaline - -	Gouverneur, New York	Ge	54

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Tourmaline -	De Kalb, New York	Ge	54
" -	Haddam, Conn.	Ge	54
" -	Dunderburg Mts., New York	Ge	54
" -	Portland, Conn.	Ge	54
" -	Gibson, New Hampshire	Ge	54
" -	Hebron, Maine	Ge	54
" -	Hebron, Maine	Ge	54
" -	Rutherford, Maine	Ge	54
" -	Chesterfield, Maine	Ge	54
" -	Winter Harbour, Cumberland Sound	Ge	54
" -	Pala, California	Ge	54
" -	Prevali, Corinthia	Ge	54
" -	Brevig, Norway	Ge	54
" -	Livinerthal, Switzerland	Ge	54
" -	Mursinsk, Siberia	Ge	54
" -	Island of Elba	Ge	54
" -	Anjanabonoina, Madagascar	Ge	54
" -	Minas Geraes, Brazil	Ge	54
" -	Wolkenberg, Saxony	Ge	54
" -	Utö Mines, Södermondland, Sweden	Ge	54
" -	Pyrenees	Al	46
" (Rubellite) -	—	Al	46
" -	—	B Li	4
" (Rubellite) -	—	Mn	75
Cerite -	I. of Gyttop	Cu Ce Sm Mn Fe	27
" -	—	Ce Nd Pr	75
Dumortierite -	Beaunans, Lyons	B	45
" -	—	B	46
Staurolite -	—	B absent	46
" -	—	B absent	45
" -	—	Fe	75
Kornerupine -	Itrongahy	B	45
" (Prismatine) -	—	B	45
" -	—	B	46
Sapphirine -	Itrongahy	B	45
" -	Fiskeraes, Greenland	B	45
" -	—	B	46

XXII. MICA DIVISION.

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Mica -	Co. Dublin	Li Na K Rb Cs Cu Ag Ca Ga Fe Mn Pb	35
Muscovite -	Fillenberg, nr. Marienbad, Bohemia	Ge	54
" -	Mursinsk, Siberia	Ge	54
" -	Winter Harbour, Cumberland Sound	Ge absent	54
" -	Winter Harbour, Cumberland Sound	Ge	54
" -	Speedway, New York City	Ge absent	54
" -	Paris, Maine	Ge	54
" -	Keene, New Hampshire	Ge	54
" -	Chaffee County, Colo.	Ge	54
" -	Mitchell Co., N.C.	Ge	54
" -	Pyrenees	Al	19
" -	—	Na K Rb Cu Ag Ca Al Ga Fe Ni Mn Pb	35
" -	—	Cs & Li absent	26
" Muscovite -	Gotthard	K absent	21
Muscovite -	Madagascar	Li Na K Rb Cs	18
" -	Suizawa, Near Ishigure, Mi-e Prefecture	Pb Cu Sc Y La Eu Ga Dy Er Nd Ce Yb Tm	39
" -	Antaboaka	Cs Rb Ga Tl Mn	25
Fuchsite -	Winnipeg River, Manitoba	Ge	54
" -	Rutland, Vermont	Ge absent	54
" -	Brunswick, Maine	Ge	54
" -	Pfitsch, Tyrol	Ge absent	54
" -	Zillerthal	Ge	54
" -	—	Cr	75
Paragonite -	—	Al	19
Lepidolite -	Silver Leaf Mine, Manitoba	Ge	54
" -	Paris, Maine	Ge	54
" -	Mount Apatite, Auburn, Maine	Ge	54
" -	Haddam Neck, Conn.	Ge	54
" -	Middletown, Conn.	Ge	54

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Lepidolite - -	Peerless Mine, Key-stone, S.D.	Ge	54
" - -	Ingersoll Mine, Black Hills, S.D.	Ge	54
" - -	Pala, California	Ge	54
" - -	Rozena, Moravia	Ge	54
" - -	Utö, Sweden	Ge	54
Lepidomelane - -	Madagascar	No Al bands	19
Lepidolite - -	—	Li Na K Rb Cs Cu	35
" - -	—	Ca Ga Tl Fe Mn Pb	
" - -	—	Ga Th	26
" - -	Rözna	K Na Li Rb Cs	4
" - -	Pala, California	K Na Li Rb Cs Tl	4
" - -	Pala, California	K Na Li Rb Cs Tl	4
" - -	Limoges	K Na Li Rb Cs Tl	4
" - -	Campo San Pietro, Elba	K Na Li Rb Cs Tl	4
" - -	Madagascar	Li Na K Rb Cs Ga	18
" - -	—	Th	
" - -	Antsongombato	Cs Rb Ga Tl Mn	25
" - -	—	Mn	75
Zinnwaldite - -	Madagascar	No Al bands	19
" - -	—	Ga Th	26
" - -	Zinnwald	K Na Li Rb Cs	4
" - -	Auburn	K Na Li Rb Cs	4
" - -	Madagascar	Li Na K Rb Cs Ga	18
" - -	—	Th	
" - -	Antaboaka	Cs Rb Ga Tl Mn	25
Biotite - -	Faraday Township, Ontario	Ge	54
" - -	Mattawa, Ontario	? Ge	54
" - -	Windham, Maine	Ge absent	54
" - -	Madagascar	No Al bands	19
" - -	—	Si Al K Li Fe Mn	72
" - -	—	Ca Mg Na	
" - -	—	Ga Th	26
" - -	Mazatand, Haute-Vienne	Ti	21
" - -	Ilmen Mounts	K Na Li Rb	4
" - -	Berwik	K Na Li Rb	4
" - -	Madagascar	Li Na K Rb Cs	18
" - -	Antaboaka	Cs Rb Ga Tl Li Mn	25
" - -	Maharitra	Ti Sc	25

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Biotite - -	Antsongombato	Ti Sr Y Ca	25
Phlogopite - -	West Portland, Quebec	Ge	54
Margarite - -	—	Al	19
Seybertite - -	—	B absent	45
" - -	—	B absent	46
Xanthophyllite - -	—	B absent	45
" - -	—	B absent	46
Venasquite - -	—	B absent	45
" - -	—	B absent	46
Waluewite - -	—	B absent	45
" - -	—	B absent	46
Chlinochlore - -	—	Fe	75
Rapidolite - -	Gothard	Li	4
" - -	Rhone Glacier	Li	4
" - -	Galenstock	Li	4
Pennine - -	Zermatt	Li	4
Masonite - -	—	B absent	46
" - -	—	B absent	45
Kammererite - -	—	Cr Fe	75
Aerinite - -	—	Sr V	51
" - -	Casseras, Aragon	Si Ca Mg V Ba	15

XXIII. SERPENTINE AND TALC DIVISION.

Serpentine - -	Lynfield, Mass.	Ge absent	54
" - -	Geisspfad	Li (rare)	4
Garnierite - -	Kanala, New Caledonia	Ni	15
" - -	New Caledonia	Ni	15
Talc - -	Rochester, New Hampshire	Ge absent	54
" - -	Fengtien, Manchuria	Ge	54
" - -	Geisspfad	Li	4
Glauconite - -	Bellegarde	Li	4

XXIV. KAOLIN SUBDIVISION.

Kaolinite - -	Tanokami	Ru	40
Britholite - -	—	Nd Pr	75
Hodgkinsonite - -	—	Mn	75
Sphene - -	—	Nb	21
" - -	Zermatt	Ca Si Ti Al	15
" - -	—	Nd	75
Mosandrite - -	—	Nd	75

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Rinkite - -	—	Nd	75
Perowskite - -	Rymfischwänge, Zermatt	Ca	4
XXV. NIOBATES AND TANTALATES.			
Pyrochlore - -	—	Nd	75
Fergusonite - -	Iyo, Shikoku	Y Yb Sc Lu Dy Tu Nd Er Eu Pr Ho Cu Pb Ge	63
„ - -	—	Sm Er	75
Sipylite - -	—	Sm Er	75
Columbite - -	Ishikawa	—	68
Samaraskite - -	Ishikawa	Y Er Dy Gd Sa Sc Tb Pb Ba Sr W	68
„ - -	—	Nd	69
Yttrotantalite - -	—	Sm Er	75
Euxenite - -	Morefjar, nr. Naeskilen	—	22
„ - -	Naeskilen	Ti	21
Betafite - -	Ambolotara	Ti	21
Aeschinite - -	—	Nd	75
Ishikawaite - -	Ishikawa	Pb Ba Sr Zn Be Y Er Gd Dy Sm La Sc Cu Bi Pb	68
„ - -	Ishikawa	Y Er Gd Dy Sa La Sc Pb Ba Sr Zn Cu Bi Pb	69
XXVI. PHOSPHATES AND ARSENATES.			
Samaraskite - -	Ishikawa	Pb Ba Sr W Y Er Dy Ga Sm Sc Tb	68 & 69
Xenotime - -	Ishikawa Hill	Pb Ba Ti Y Sc Nd Gd Dy Er Yt Lu	43
„ - -	—	Er Sm	75
Monazite - -	Naegi	Ce Nd La Sm Pd Dy Yt Ga Er Eu Tb Y Ho Tl Lu	66
„ - -	Ishikawa	Ce La Nd Pr Y Dy Gd Er Yb Ho Tb	68
„ - -	Kararfvet	Cu La Ce Pr Nd Sm Gd Fe Pb Th Y	27
„ - -	—	Nd Pr	75
Manganapatite - -	—	Ca P Mn Fe Al Mg Si	72

<i>Mineral</i>	<i>Location</i>	<i>Elements</i>	<i>Reference</i>
Pyromorphite - -	Gennamari Arbus, Sardinia	Nd	50
Vanadinite - -	—	Cu V Co	75
Amblygonite - -	—	Al Li P Si Fe Ca Na Mg	72
Roselite - -	—	V Co	75
Erythrite - -	—	V Co	75
Rhabdophanite - -	—	Nd Pr	75
Churchite - -	—	Nd Pr	75
Torbernite - -	Sabugal	P U Cu Ca V Al Fe Ra Ba Pb Mn Mg Tl As Sn Bi	55
„ - -	Nellas	P Cu Ca U Al Fe V Ra Ba Pb Mn Zn As Sn Bi Mg Tl	55
Autunite - -	Nellas	P Ca Cu U Al V Fe Pb Mn As Sn Bi Mg Tl	55
XXVII. BORATES AND URANATES.			
Zeunerite - -	—	U	75
Uranospinite - -	—	U	75
Uranocircite - -	—	U	75
Stassfurtite - -	Stassfurt	Na K Fe Sr Ni	32
Rhodizite - -	Manjaka	Cs Rb Ga Tl Li Be	25
Parisite - -	—	Nd Pr	75
Uraninite (Broeggerite) - -	—	He	7
„ (Cleveite) - -	—	He	7
Pitchblende - -	Colorado	Zr Sc Hf	9
XXVIII. SULPHATES, CHROMATES.			
Barytes - -	—	Ba S	15
„ - -	Binnenthal	Ba	4
Celestine - -	Sicily	Sr Ba S	15
Anhydrite - -	Simplon	Sr	4
Crocoite - -	Tasmania	La Ce Sm Y Er Eu Gd Ho Zr Ca Nd Th Nb Sr Al Tb Dy Ba	5
Kainite - -	Stassfurt	Na K Fe Sr Mn	32
Linarite - -	—	Cu	75
Gypsum - -	Buttes, Chaumont	Ca S	15
„ - -	Bex	Sr Li	4

Mineral	Location	Elements	Reference
Gypsum - -	Granges, Valais	Little Sr or Li	4
Kieserite - -	Stassfurt	Na K Fe	32
Epsomite - -	Stassfurt	Na K Fe Sr Ni	32
Chalcanthite - -	—	Cu	75
Gilpinite - -	—	U	75
Uranochalcite - -	—	U	75
Voglianite - -	—	U	75
Wulfenite - -	Bleiberg	Ce La Nd Sm Y Er	5
		Tb Ba Rh ? Gd Eu	
		Pt ? Lu Ni Cr Fe Al	
		Ca Sr	

XXXIX. TUNGSTATES.

Scheelite - -	Traversella Piedmont	Nd Pr	75 & 2
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